Operation of the Montana Regional Seismograph Network

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Investigations Undertaken (October 1, 2004 – September 30, 2005)

This award in combination with funding from the State of Montana and from the Confederated Salish and Kootenai Tribes provides the principal support for the operation of the Montana Regional Seismograph Network (MRSN) by the Earthquake Studies Office of the Montana Bureau of Mines and Geology. The MRSN currently consists of 39 seismograph stations (Figure 1). Four of these stations are National Seismic Network backbone broadband seismographs operated cooperatively with the US Geological Survey in Golden, Colorado. Seven stations supported by the Confederated Salish and Kootenai Tribes operate in the Flathead Valley in northwestern Montana. Signals from these six short-period vertical stations and one 4-component digital station (three strong-motion components and one weak-motion vertical component) are radio-telemetered to the Tribal Safety of Dams office in Ronan, digitized on an Earthworm data acquisition system, and forwarded to the Earthquake Studies Office in Butte via Internet. A second Earthworm node at the University of Montana in Missoula digitizes data from five short-period vertical stations in west-central Montana and forwards the data to Butte. The most recent addition to the MRSN is a broadband station installed August 12 by the USGS with cooperation from the Montana Bureau of Mines and Geology following a significant earthquake in southwest Montana (discussed below).

At the Earthquake Studies Office in Butte, the Earthworm-based system acquires real-time data from the two remote nodes in northwestern Montana, digitizes data from 22 short-period stations in southwestern Montana, and receives data from 44 stations in eight other seismograph networks operating in surrounding areas of Idaho, Wyoming, Washington, South Dakota, and Canada. In total, 120 channels of data from 78 stations are recorded at the Earthquake Studies Office, including 53 channels from 39 Montana stations. Selected broadband stations are filtered to produce 32 additional short-period and long-period channels. The Earthquake Studies Office uses data from these seismic stations to catalog and report on seismicity in the Northern Rocky Mountain region. Selected MRSN data are also exported in real-time to the US Geological Survey National Earthquake Information Center, the University of Utah Seismograph Stations, BYU Idaho, the Idaho National Engineering and Environmental Laboratory, the University of Idaho, and the University of Washington. All MRSN data flows to the IRIS Data Management

Center (DMC) in real-time. Raw seismic data along with automatically determined hypocenter locations and reviewed hypocenter locations are posted on the Earthquake Studies Office web site http://mbmgquake.mtech.edu.

Results

During the period October 1, 2004 through September 30, 2005, the Earthquake Studies Office determined hypocenter locations for 1732 earthquakes with magnitudes ranging from –0.3 to 5.6 (Figure 2). A total of 513 earthquakes that occurred during this period remain to be located; 110 smaller (M <2) during the first 48 hours after the Dillon main shock, and 403 earthquakes for the period July 29, at 12:00 UTC through August 31, 2005. For the month of August 2005, only the seven largest Dillon aftershocks that were felt (M 3.1 – 3.9) have been located. The Dillon earthquake aftershock sequence has placed unprecedented workload on the Earthquake Studies Office analysis capabilities. This backlog of un-analyzed events will be addressed as time and resources permit.

The largest Montana earthquake in 41 years occurred on July 26, 2005. This magnitude 5.6 earthquake occurred along the western edge of the Intermountain Seismic Belt 16 km north of Dillon in a region of previously low seismicity. The earthquake was felt throughout the northern Rocky Mountain region (http://pasadena.wr.usgs.gov/shake/imw/STORE/Xazad_05/ciim_display.html) with a maximum Modified Mercalli Intensity of VI at Dillon. The earthquake damaged over 50 masonry structures in Dillon (mainly chimneys), including the grade school, high school, public library, and several buildings on the campus of the University of Montana Western. Old Main Hall, the original historic building on campus sustained severe damage to a large chimney, which was promptly removed to prevent total collapse. Work is ongoing to repair damage to structural masonry walls in other parts of the building. A USGS National Strong Motion Program instrument on the UM Western campus recorded a peak horizontal ground acceleration of 12.7% g. An overpass on Interstate-15, 6.3 km southwest of the epicenter sustained damage when bridge beams shifting on their foundation sheared anchor bolts. Ground cracks with up to with up to 10 cm of vertical displacement formed at a site approximately 3 km southwest of the epicenter underlain by alluvial fan deposits. These cracks developed in response to strong shaking in weak soils and are not related to primary fault displacement.

Preliminary analysis of the Dillon earthquake indicates that it occurred at a depth of 10.5 km below the surface on a normal fault trending N11˚W and dipping 50˚E along a fault lacking recognized Quaternary surface expression. The densest concentration of the 345 aftershocks located during this reporting period (Figure 3) defines an oblong area measuring 7 km N-S by 4.5 km E-W. Typical aftershock locations since installation of the new Dillon station have horizontal uncertainties of 0.5 km and vertical uncertainties of 0.4 km. Viewed in cross-section (Figure 4) the main shock and early large aftershocks cluster near the bottom of the aftershock zone and suggest an eastward dipping zone. Later aftershocks appear to occupy a wedge-shaped volume lying directly above the inferred fault plane.

In addition to the Dillon earthquake sequence, 51 earthquakes had magnitudes of 3.0 or larger and 215 earthquakes had magnitudes of 2.0 or larger. The largest of these in Montana was a magnitude 3.6 earthquake in the Gravelly Range west of the Madison Valley. Nine earthquakes were reported as felt. The vast majority of seismicity occurred along the northern Intermountain Seismic Belt and the Centennial Tectonic Belt. Earthquakes located outside these two active seismic belts included five earthquakes east of the Rocky Mountains in southern Canada and north-central Montana. We analyze only larger earthquakes from Yellowstone National Park when the MRSN provides significant additional data; their locations are typically fixed at hypocenter coordinates determined by the University of Utah Seismograph Stations. During this reporting period, 33 earthquakes are reported within the Yellowstone Network authoritative region.

We made 15 trips to 9 sites to perform repairs during the reporting period. The majority of field work to resolve telemetry noise problems and improve station reliability was conducted after this reporting period in October 2005.

The Wood-Anderson-equivalent seismograph at Butte (BUT) has served as the primary instrument for determining local magnitudes (M_L) for Montana earthquakes since 1936. This instrument is recorded by pen and ink on paper seismograms beginning December 1982 and is also recorded digitally on the Earthworm system in Butte beginning on October 22, 2004. Instrument response files were determined during this project period and we are now able to compute M_L from the digital seismograms. Work is in progress to characterize the differences in BUT M_L determined from paper seismograms and digital records.

A significant effort not charged to this grant, but relevant to the MRSN, was the selection of two new National Seismic Network (NSN) backbone stations sites in central Montana. A site for the north-central Montana station near Eagleton was sited in April and opened in late November. The sixth and final Montana USNSN backbone site was selected in June in south-central Montana at the Yellowstone-Bighorn Research Association geology field camp south of Red Lodge Montana near the northeastern tip of the Beartooth Mountains. All NSN backbone stations in Montana were selected, permitted, installed and are operated as a cooperative effort between the US Geological Survey National Seismic Network program and the Montana Bureau of Mines and Geology.

In August we helped Boise State University (BU) personnel setup their new Earthworm system to export data from three southwestern Idaho station to the Earthquake Studies Office.

Seismograph Stations 10/1/04 - 9/30/05

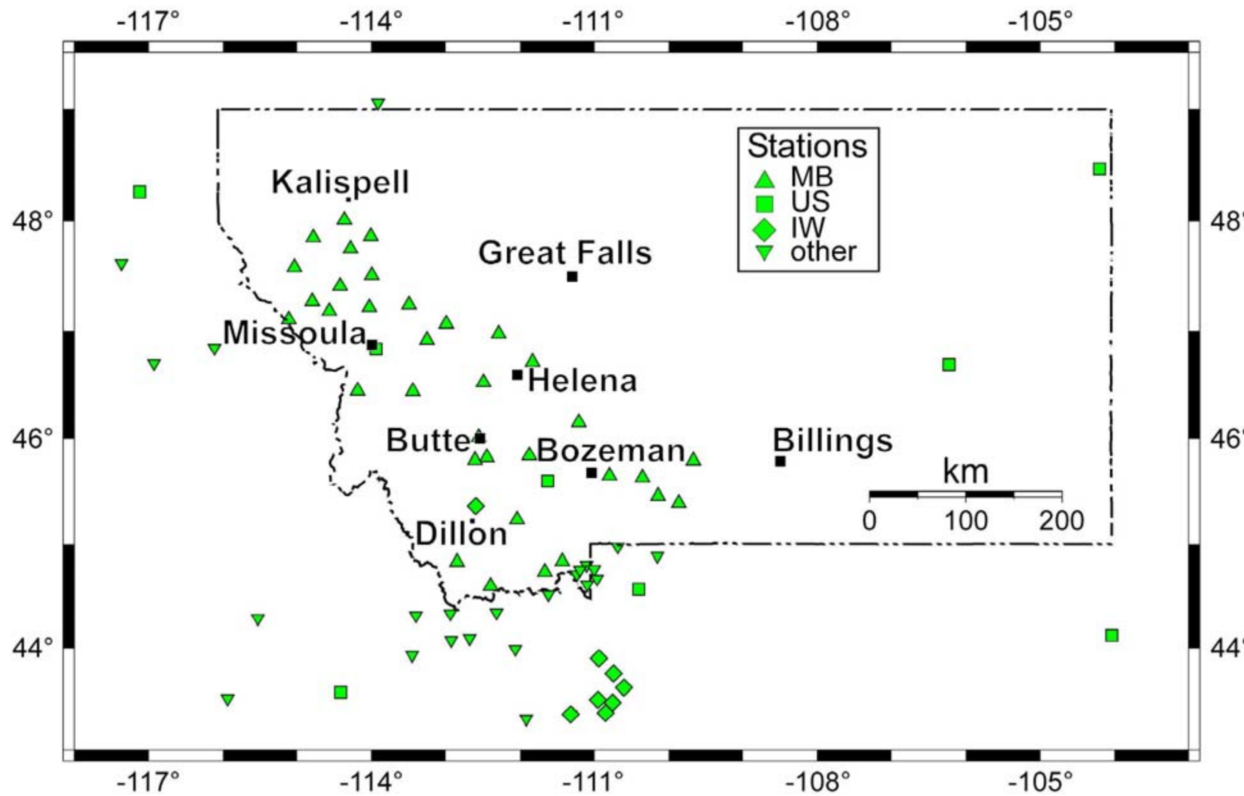

Figure 1. Seismograph stations of the Montana Regional Seismograph Network (upright triangles), US National Seismograph Network (squares), Intermountain West Network (diamonds), and surrounding regional networks (inverted triangles) used to locate regional seismicity. These stations were recorded in real-time using Earthworm as of September 2005. Surrounding networks include: Canadian National Seismograph Network; University of Idaho, University of Washington, Boise State University, Idaho National Laboratory, Brigham Young University Idaho, and the University of Utah Yellowstone Network. Note that some surrounding network stations lie beyond the region shown by this map.

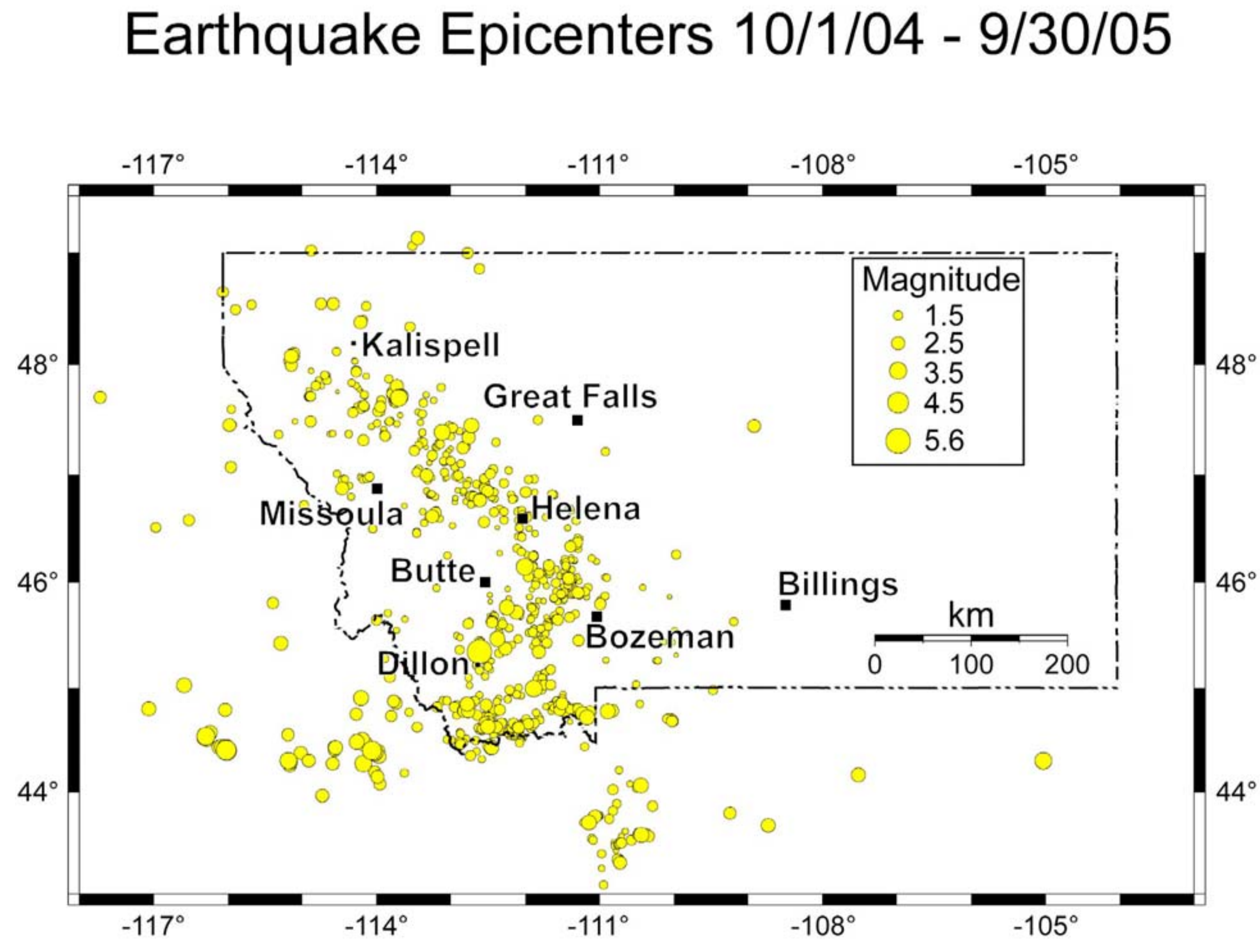

Figure 2. Map of 1732 earthquake epicenters determined from the Montana Regional Seismograph Network for the period October 1 – September 30, 2005. The northern Intermountain Seismic Belt extends from the northwest corner of Wyoming northwestward to the Kalispell area. The Centennial Tectonic Belt extends from the northwest corner of Wyoming westward through southwest Montana (south of Dillon) into east-central Idaho.

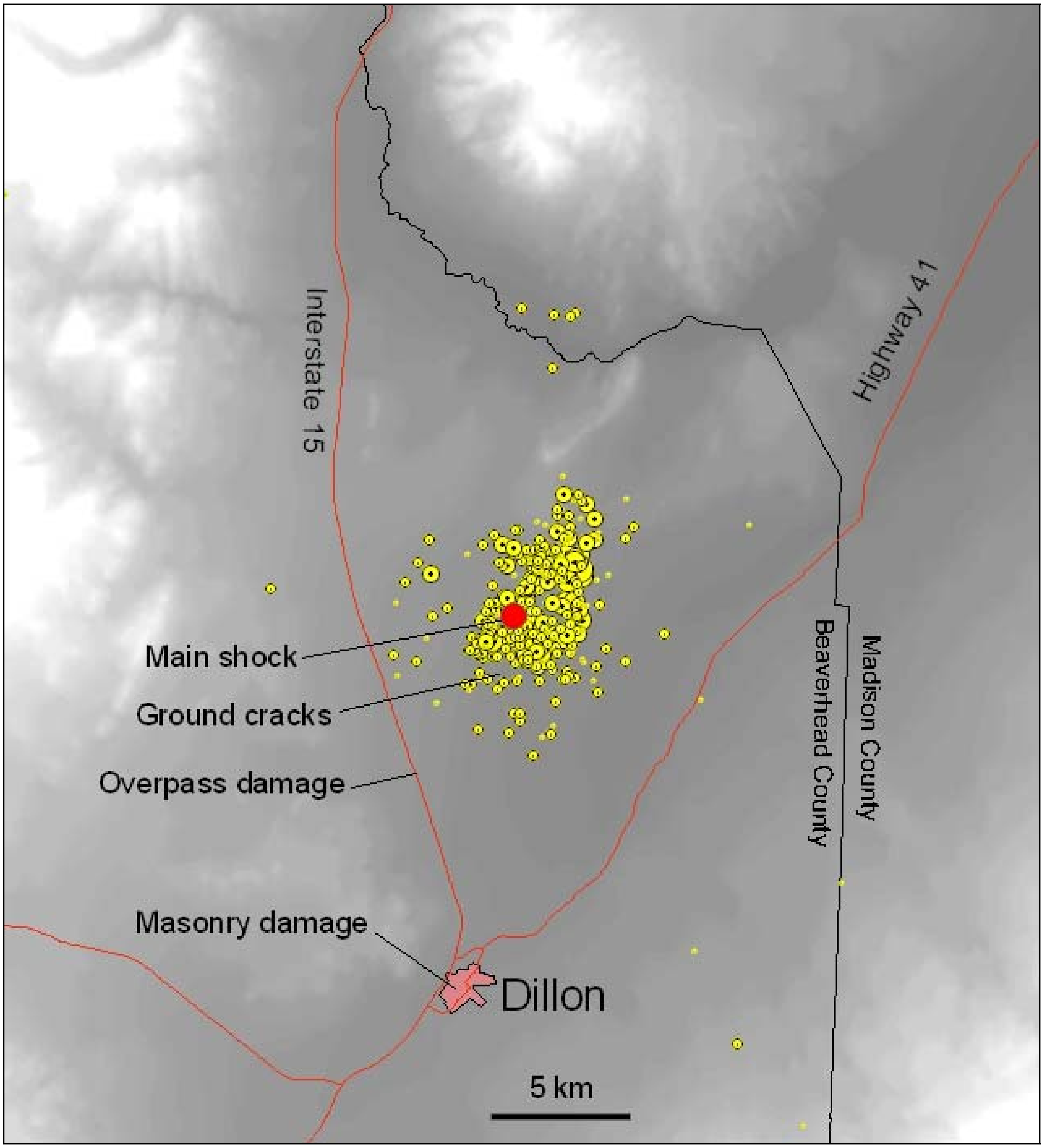

Figure 3. Map of the Dillon main shock and 345 aftershocks that occurred from July 26 through September 30, 2005 and sites affected by the main shock ground motions. Shades of grey indicate topography, with darker areas having lower elevation and lighter shades showing mountains.

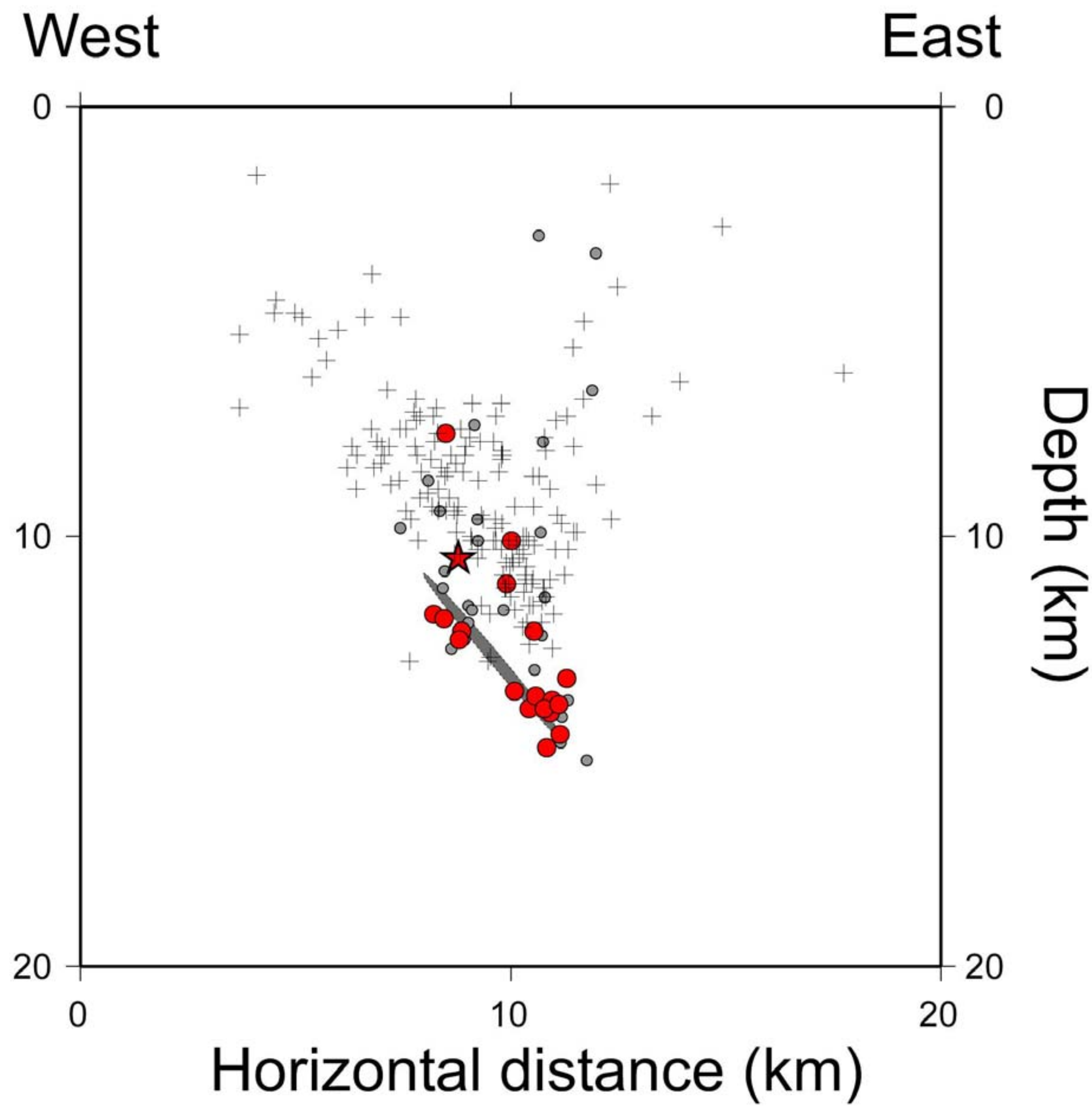

Figure 4. Northward cross-sectional view of the Dillon main shock (star) and early aftershocks of magnitude 3.0 or greater (red circles). Grey circles are early aftershocks with magnitudes less than 3.0 and plus symbols are aftershocks of all magnitudes (but mainly smaller than 3.0) that occurred during September 2005. The grey ellipse schematically represents the fault plane with normal displacement inferred from the distribution of early aftershocks and fault plane solution nodal planes of the main shock and three of the largest aftershocks.

Non-technical Summary

This cooperative agreement provides partial support for maintenance and operation of the Montana Regional Seismic Network. During the report period one new seismograph station was added to the 39-station network. Seismic network data is archived in real time at the IRIS Data Management Center. From October 1 to September 30, 2005, a total of 1732 earthquakes were located. The largest was a magnitude 5.6 shock on July 26 in southwest Montana that caused some damage in Dillon. Over 3000 aftershocks followed the main shock. Seventy-nine earthquakes had magnitudes of 3.0 or greater and 23 earthquakes were reported felt.

Reports and Publications

Stickney, M.C., (in preparation) Montana Seismicity Report for 2004; submitted to the Montana Bureau of Mines and Geology as a Miscellaneous Contribution.

Wong, I., Olig, S., Dober, M., Wright, D., Nemser, E., Lageson, D., Silva, W., Stickney, M., Lemieux, M., and Anderson, L., 2004, Probabilistic earthquake ground motion hazard maps for Montana: Montana Bureau of Mines and Geology Special Publication 117, 72 p. plus CD.

Zeiler, C.P., Stickney, M. C., and Speece, M. A., 2004, Revised Velocity Structure of Western Montana; Bulletin of the Seismological Society of America, v. 95, p. 759-762.

Data Availability

Seismic event waveform data archived at the Montana Bureau of Mines and Geology Earthquake Studies Office are available in SAC format upon request. Continuous waveform data from the Montana Regional Seismic Network are also available from the IRIS DMC using their SeismiQuery Web tool at URL: http://www.iris.washington.edu/SeismiQuery. Earthquake catalog data for the Montana region are available on the Advanced National Seismic System's composite earthquake catalog at URL: http://quake.geo.berkeley.edu/cnss/cnss-catalog.html or by request from Mike Stickney at the contacts below. Recent hypocenter information is available from the Montana Bureau of Mines and Geology website: http://mbmgquake.mtech.edu.

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